Quarterly Progress Report

Project No. DE-FC26-05NT42304

Lovelace Biomedical and Environmental Research Institute
Albuquerque, NM

Health Effects of Subchronic Inhalation of Simulated Downwind Coal Combustion Emissions

Quarter 4

November 1, 2005 – January 31, 2006

Project Director: ______________________ Date 2/17/06

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1. Executive Summary

This Report describes progress during the fourth calendar quarter of project DE-FC26-05NT42304 "Health Effects of Subchronic Inhalation of Simulated Downwind Coal Combustion Emissions". The project was initiated on February 3, 2005. The first quarterly report described progress through April 2005. The second and third reports described progress through July 2005 and October 2005, respectively. This fourth report describes progress through January 2006.

The purpose of this project is to conduct a comprehensive laboratory-based evaluation of selected respiratory and cardiac health hazards of repeated, subchronic (up to 6 months) inhalation of simulated key components of "downwind" emissions of coal combustion. This project is being performed as an integral part of a joint government-industry program termed the "National Environmental Respiratory Center" (NERC), which is aimed at disentangling the roles of different physical-chemical air pollutants and their sources in the health effects associated statistically with air pollution. The characterization of the exposure atmosphere and the health assays will be identical to those employed in the NERC protocols used to evaluate other pollution source emissions.

The project has two phases, each encompassing multiple tasks. Guidelines for the composition of the exposure atmosphere were set by consensus of an expert workshop. The capability to generate the exposure atmosphere, and pilot studies of the comparative exposure composition using two coal types, will be accomplished in Phase 1. In Phase 2, the toxicological study will be conducted using one of the coal types tested in Phase 1. This project provides 50 % support for the work in Phase 1 and 20% support for the work in Phase 2.

Work d*uring this reporting period, included completion of Phase 1, Task 1 (assemble drop-tube furnace and dilution/modification system) and progress on Phase 1 Task 2 (conducting iterative generation trials with Powder River Basin [PRB] coal. The original schedule called for completion of Phase 1 Task 2 by the end of December 2005. Problems encountered with the reliability and consistency of operation of the coal aerosolizing system required system development work that was unanticipated from the successful use of the original dust generator at EPA and LRRI for short-term generation. Alternate generation methods were explored, and a screw feeder-based method was developed, tested, and proven reliable. Generation trials with PRB coal resumed and are nearly, but not totally, completed. Because of this unanticipated delay, the project is approximately two months behind schedule at this reporting point. However, this lag may be reduced in subsequent tasks. As reported earlier, the animal exposure system was constructed ahead of schedule. Not only will this save time later in the project, but it is also allowing the generation trials to be conducted with measurements in the actual animal chambers, instead of in the mixing chamber as originally planned. Progress during this reporting period included:*

- *Both the PRB and the Central Appalachian low-sulfur bituminous (CALS) coals were obtained, and chemical analyses were initiated.*
- *A new screw feeder-based coal aerosolizer was developed.*
- *Combustion trials were initiated with PRB coal, and iterative adjustments to the generation system and co-pollutants were made to come progressively closer to the target mixture. These trials are continuing at present.*

2. Results of Work During Reporting Period

a. Approach

The general approach taken in this project has not changed from that described in the application. The approach to Phase1, Task 1, involves: 1) collecting information on the use of drop-tube furnaces for laboratory-scale coal combustion; 2) collecting information on potential coal types and resources for obtaining coal and processing it for use in the laboratory; 3) finalizing a design for the drop-tube furnaces to be used in this project; obtaining processed coal; 4) obtaining, installing and testing the furnaces; 5) developing and testing the coal aerosol generator; 6) assembling the emissions generation/modification system; and 7) confirming system operation by generating coal emissions. The project then proceeds to Phase 1, Task 2 which involves conducting iterative generation trials with PRB coal in an attempt to meet the target ratios of particulate and non-particulate components at target total particle mass concentrations. Task 3 then repeats the iterative generation trials with CALS coal to determine: a) differences in composition of the atmosphere when all operating parameters are identical to those used for PRB coal, and b) whether or not the target exposure composition can be achieved with CALS coal.

The last progress report described progress toward accomplishment of Phase 1, Task 1 items 6 and 7. We have now completed all items under Phase 1, Task 1, and have nearly completed Phase 1, Task 2. At this point, the project is approximately two months behind schedule, due to our discovery durin g the iterative generation trials that the coal aerosolizing system (EPA design) was not sufficiently reliable for long-term daily use. The extended schedule is largely attributable to the delay incurred by having to develop and validate a completely new approach to generating the coal aerosol.

b. Activities and Progress

1. Characterization of Coal

The Powder River basin Sub-Bituminous (PRB) and the Southern Appalachian Low Sulfur Bituminous (CALS) coals are currently being characterized by standard Proximate and Ultimate analyses at Geochemical Testing Inc. based in Somerset, PA. This analytical strategy and source were recommended by UND/EERC, and will provide a characterization comparable to that used throughout the industry.

The "proximate" analysis (ASTM D-5142) gives moisture content, volatile content (when heated to 950 C), the free carbon remaining at that point, the ash (mineral) in the sample and the high heating value (HHV) based on the complete combustion of the sample to carbon dioxide and liquid water. The "ultimate" analysis (ASTM D-3176) gives the composition of the biomass in weight% of carbon, hydrogen and oxygen (the major components) as well as sulfur and nitrogen (if any).

2. Management of Coal

For long-term storage, the coals are contained in closed containers under nitrogen to purge oxygen that might oxidize the coal. During the past quarter, we developed an enclosure that provides for storage of the coals in an inert atmosphere. The coals have a constant stream of high purity nitrogen flowing (at 1 liter per minute) over them at all times. The nitrogen is generated from a PEAK nitrogen generator that produces 99 % pure nitrogen.

3. Modification of the Coal Aerosolization system:

The initial coal aerosol generation system, following the design used at EPA, proved insufficiently robust for long-term, daily operation. After exploring alternatives, an approach was developed that uses a screw-feeder to supply coal directly to the air stream that transits the coal aerosol to the furnace. The screw feeder has proven to yield consistent aerosol generation, and the system is much more robust than the previous aerosol generation system. Figure 1 below shows the interface between the screw feeder and the furnace. The screw feeder introduces pulverized coal directly into a vertical airstream immediately before it enters the furnace. Figure 2 shows a technician loading the screw feed “hopper” with coal.

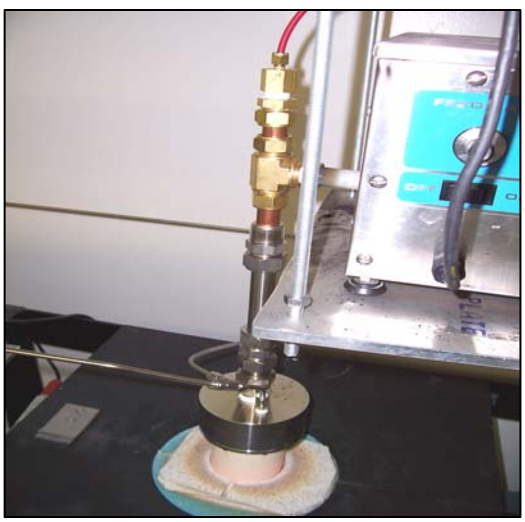

Figure 1. Point of Introduction of Coal from Screw Feeder Into the Airstream Just Above the Furnace

Figure 2. Technician Loading the Screw Feeder Hopper

4. Modification of the Ash Transit line:

One of the challenges associated with the integration of multiple components from multiple sources into a single mixture is the balance of flows throughout the system. A key determinant of flows throughout the system is the required 28 liters per minute

(LPM) at the cyclone used to remove larger ash from the furnace effluent. In the original system configuration, we had trouble maintaining this flow while balancing flows in the remainder of the system. In order to maintain this flow, we have installed an Air-Vac into the transit line downstream of the first coal effluent expansion chamber. An Air Vac is a venture-based device that uses a sidestream of pressurized air to accelerate and control a mainstream of air. The Air-Vac is used to define and stabilize the total flow through the furnace, and it is also the first-stage dilution of the furnace effluent. The exhaust of the Air-Vac combines with the transit line from the sulfate generation system just prior to entering the 1 m^3 mixing chamber. A second Air Vac is used for the sulfate flow. Figure 3 shows the primary coal mixing chamber, the Air-Vacs, and the point of introduction of sulfate into the transit line to the mixing chamber.

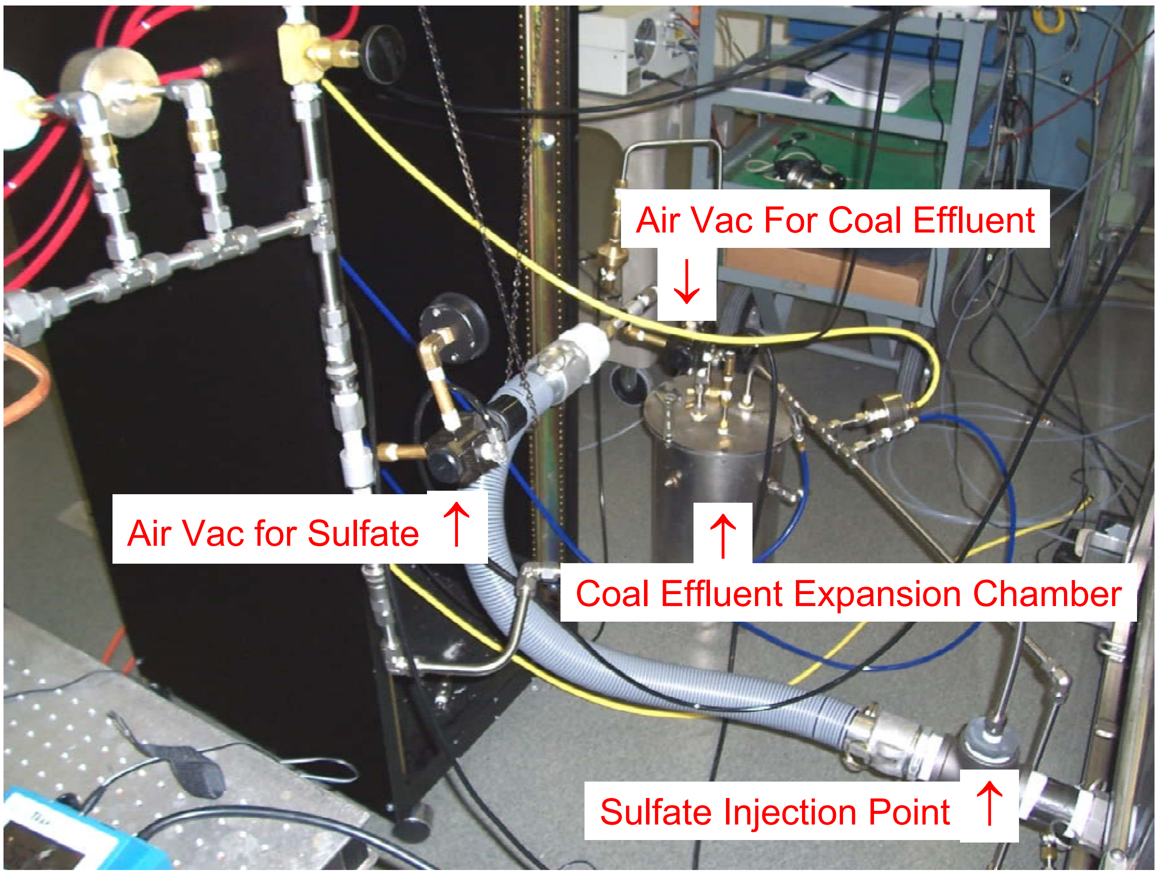

Figure 3. Position of the Air Vac Between the Coal Furnace Effluent Expansion Chamber and the Mixing Chamber, Showing the Point at Which the Sulfate Aerosol is Added to the Airstream.

5. Testing and Characterization of the Coal Ash Generation System

Much of the effort during the past quarter was aimed at testing the robustness of the coal ash generation system. As indicated above, the initial testing led to modification of the system. In testing the ash generation system, there were several key robustness and performance benchmarks that we targeted. First, we required an aerosol generation approach that could deliver aerosol consistently 6 h/day for multiple months of continuous operation. Although the time to date has not allowed us to test for several months, the modified system appears to be reasonably stable, and compared with the previous aerosol generation system, its simplicity should allow for much more straight-forward troubleshooting should problems arise. Next, we adopted several performance benchmarks defined both by the NERC coal workshop participants and by recommendations from UND/EERC and other organizations. These performance benchmarks were aimed at ensuring efficient combustion, and included:

- Carbon Monoxide concentration should be less than 10 ppm from the furnace
- Carbon burnout should be as complete as possible, resulting in a carbon concentration that accounts for less than 10 % of the PM mass.
- For PRB coal, the color of the ash should be yellow-red, not gray or black.

Under our coal feed and furnace conditions, our present results indicate that we are that we are meeting these benchmarks. Carbon monoxide concentration from the furnace is typically about 1 ppm. Carbon mass, although some carbon analysis results are still pending, appears to be near or less than 10 % of the mass. Figure 4 below shows the ash composition (carbon results pending) from the PRB coal. These data were produced from X-Ray fluorescence analysis of ash collected on a Teflon membrane filter. Note the metals (and some non-metals, including sulfur) account for approximately 90 % of the mass of material weighed on the filter.

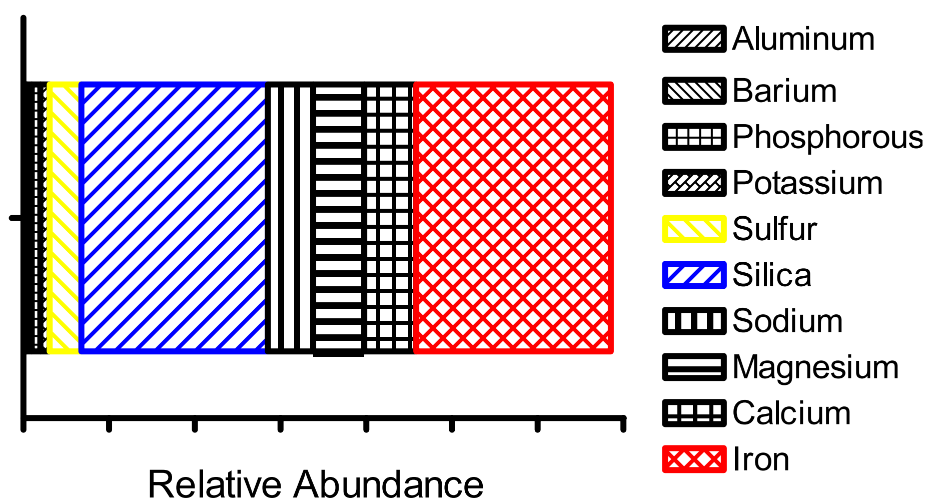

Figure 4. Relative Contributions of 10 Most Abundant Metals and Non-Metal Elements in PRB Ash Collected from Frnace Effluent After Removal of Supermicron Particulate Matter (PM) [Large PM was removed by passing the effluent through a cyclone. Carbon analysis still pending. The sum of the metals and sulfur accounted for approximately 90 % of the mass weighed on the filter.]

Further evidence that the PRB ash is being efficiently burned is that the color of the ash matches what is expected for this type of coal. The photograph in Figure 5 below shows burned and unburned PRB coal collected on two separate filters, illustrating the change in color suggestive of carbon burnout.

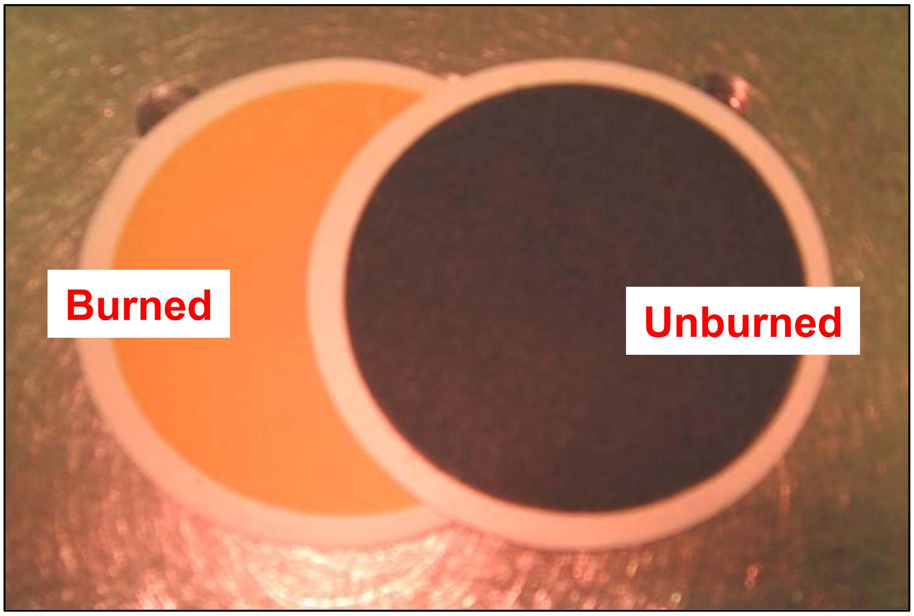

Figure 5. Filters Containing Burned and Unburned PRB Coal PM

Overall, we have made significant progress towards defining the aerosol generation and operational characteristics required for the PRB coal. With this experience, we expect that the development of the CALS coal atmosphere will require considerably less time than that expended on PRB coal.

6. Introduction of Gases

First, the concentrations of gases resulting from burning of the PRB coal were measured to evaluate the need for addition/subtraction of all three gases. In each case, the gas concentrations were present in the effluent from the drop-tube at concentrations below the exposure atmosphere target. In order to achieve the target gas concentrations, gases must be metered in separately until the desired mixture is achieved. The key gases, SO_2, NO, and NO_2 were purchased in gas cylinders at concentrations of ~50 ppm. The gas cylinders were connected to rotameters that are used to control flows through the gas transit lines to the primary mixing chamber. Gases are transited to the mixing chamber through ¼” Teflon tubing. Gas concentrations are adjusted by adjustment of the flows using the rotameters adjacent to the supply cylinders. We have demonstrated that we are able to introduce all of the gases and hit the target concentrations.

7. Mixing of All Components to Achieve the Final Atmosphere

We reported on the characterization of the sulfate generation system in the last quarterly report. As indicated above, we are now in a position to combine the sulfate, ash, and gases to achieve the final atmosphere. We are now in the midst of generation trials with PRB coal that include all components of the mixture, and are nearing our target composition.

b. Results and Discussion

The only results produced during the quarter are those described above. There are no other specific technical results or data to report at this time.

c. Conclusions

The project continues to appear technically feasible and should progress as planned, although difficulties with the coal aerosol generator has delayed progress by approximately two months. Generation trials with PRB coal are nearly complete.

3. Milestones

The milestones pertinent to this reporting period have not been met as originally planned. Phase 1, Task 2 was to have been completed by the end of December 2005, and we estimate now that we will complete this task by the end of February 2006 – a delay of two months. We will initiate work on Phase 1, Task 3 (generation trials with CALS coal) as soon as we have hit the target exposure composition with PRB coal. The impact of the delay during this quarter on the overall project schedule will depend on how rapidly we can transition from PRB to CALS coal, and how different the furnace effluent is with the second coal.

4. Cost and Schedule Status

a. Cost Status

DOE expenses as of 1/31/06:	$ 224,510.70
LRRI cost share as of 1/31/06:	$ 44,902.14
Other cost share as of 1/31/06:	$ 179,608.56
Total expenditures as of 1/31/06:	$ 449,021.40

b. Schedule Status

The project is two months behind the original schedule.

5. Significant Accomplishments

Significant accomplishments during the past quarter were described in detail above. In summary, we have to date:

- Completed assembly of the generation/modification/exposure system
- Received both coal types and initiated detailed chemical analysis
- Developed and tested a new coal aerosol generation system
- Conducted generation trials with PRB coal, with good indications that we are nearing our target exposure composition

6. Problems, Delays, and Corrective Actions

We have not encountered any problems or delays that have obstructed progress significantly.

7. Technology Transfer Activities

There have been no technology transfer activities or issues to date. It is not anticipated that this project will generate any intellectual property or technical advances that will raise technology transfer issues. The product of this project is explicitly information on the health effects of exposure to modified coal emissions, and that information is to be communicated to the scientific community, public, and other stakeholders through peer-reviewed, open literature publications.